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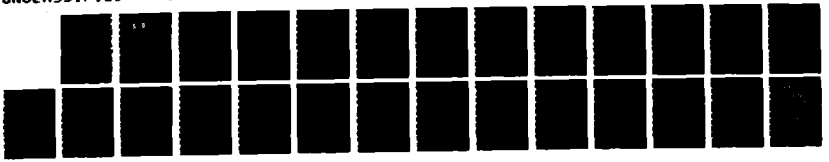

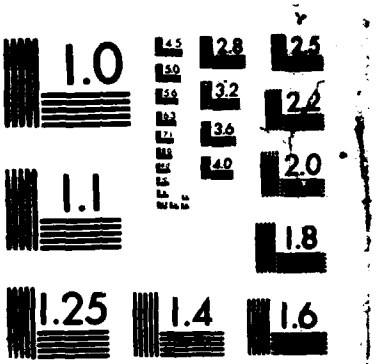

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This report describes the progress made during the first year of an equipment grant which has provided a common computing environment for four laboratories conducting research in perception and cognition at the University of Minnesota. Research in the Cognitive Psychology Laboratory has shown that learning a procedural skill can occur in the absence of any declarative learning. Progress has also been made toward developing a computer model of this process. In the Visual Psychophysics Laboratory several image-enhancement algorithms have been developed as well as a psychophysical procedure for evaluating those algorithms. Research in the Auditory Psychophysics Laboratory has concentrated on developing a model of the detection and recognition of complex auditory signals by human observers. A subset of the model has been implemented as a computer simulation and several experiments have been completed to guide its future direction. In the Psycholinguistics Laboratory a computer model

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19. of text comprehension and recall has been constructed. Several experiments have completed that confirm assumptions built into the model and show a good correspondence between its performance and that of human subjects.

# COMPUTING SUPPORT FOR BASIC RESEARCH IN PERCEPTION AND COGNITION

Charles R. Fletcher, Gordon E. Legge, Mary Jo Nissen,
and Neal F. Viemeister
Department of Psychology
University of Minnesota
75 East River Road
Minneapolis, MN 55455

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## Abstract

This report describes the progress made during the first year of an equipment grant which has provided a common computing environment for four laboratories conducting research in perception and cognition at the University of Minnesota. Research in the Cognitive Psychology Laboratory has shown that learning a procedural skill can occur in the absence of any declarative learning. Progress has also been made toward developing a computer simulation of this process. In the Visual Psychophysics Laboratory several image-enhancement algorithms have been developed as well as a psychophysical procedure for evaluating those algorithms. Research in the Auditory Psychophysics Laboratory has concentrated on developing a model of the detection and recognition of complex auditory signals by human observers. A subset of the model has been implemented as a computer simulation and several experiments have been completed to guide its future direction. In the Psycholinguistics Laboratory a computer model of text comprehension and recall has been constructed. Several experiments have been completed that confirm assumptions built into the model and show a good correspondence between its performance and that of human subjects.

This report describes the progress made during the first year of grant AFOSR-86-0280, "Computing support for basic research in perception and cognition". This equipment grant has provided a common computing environment, a network of Sun workstations and IBM micro-computers, for four laboratories within the Psychology Department at the University of Minnesota. These laboratories include the Visual Psychophysics Laboratory headed by Gordon E. Legge, the Auditory Psychophysics Laboratory directed by Neal F. Viemeister, Mary Jo Nissen's Cognitive Psychology Laboratory, and the Psycholinguistics Laboratory directed by Charles R. Fletcher. Most of the first year of the grant has been spent acquiring, installing, and learning to use computing equipment. But substantive progress has been made, and should continue at an accelerated pace during the second and final year of the grant. The following sections of this report describe the research goals of each laboratory and the progress that has been made toward achieving those goals.

## Acquisition of Skilled Performance

One objective of the research conducted in the Cognitive Psychology Laboratory was to investigate the relation between the acquisition of declarative and procedural knowledge in terms of their time course and potential interaction. Substantial progress has been made toward this goal. Using a pair of model tasks and methods for selectively tapping procedural and

declarative knowledge of a repeating spatial sequence, some healthy subjects were found to demonstrate robust procedural learning of the sequence in the absence of declarative knowledge of the sequence. One of the model tasks, the serial reaction time (SRT) task, requires subjects to make a speeded response on each trial to a light appearing in one of four locations on a video monitor. A particular ten-trial sequence of light positions is repeated throughout a block of 100 trials. Learning of the sequence is evaluated implicitly by measuring facilitation of performance - i.e., by determining whether practice reduces RT to the repeating sequence as compared to a random sequence. The second model task, the generate task, is used to measure subjects' explicit knowledge of the sequence. The task is formally similar to the SRT task; the same stimuli and responses are used. However, subjects are instructed to respond to where they think the next stimulus will appear, rather than to where the current stimulus is.

The latencies of subjects' responses to stimuli appearing in a repeating sequence decreased by 100 msec, yet when they were asked to generate the sequence they performed at chance. Additionally, they showed no savings in learning the sequence declaratively. This finding shows that procedural knowledge is not necessarily derived from pre-existing declarative representations of the same information. Although the two memory systems may interact in that way in the acquisition of some skills, it appears from our work that procedural learning in

normal subjects (as well as amnesic patients) is capable of proceeding in the absence of prior declarative knowledge.

When the amount of training subjects received in responding to the sequence was varied, it was found that increased training produced greater procedural learning of the sequence and more explicit declarative knowledge of it as well. These parallel trends appear to reflect the parallel acquisition of knowledge in separate memory systems. It is important to note that this experiment examined incidental learning in the two systems. Current experiments are investigating the possibility that the intention to learn, and the mnemonic strategies accompanying that intention, may provide a greater advantage to the declarative system. That investigation involves nonamnesic subjects as well as individuals with memory disorders following electroconvulsive therapy.

Additional research completed during the past year addressed two related questions. The first was whether procedural learning in this situation is primarily perceptual or primarily motor, and the second involved the task-specificity of procedural learning. By providing subjects with training on a task that provided either a repeating perceptual sequence, a repeating motor sequence, or no repetition and determining their subsequent performance on a transfer task, it was shown that what is learned in this model task is neither solely perceptual nor solely motor. Instead, what is learned incorporates both elements: The nature of the learned representation could be characterized as a series

of production rules mapping stimuli onto responses or as a series of connections between input and output elements.

These results also demonstrated a remarkable specificity of procedural knowledge. There was virtually no transfer of skill to another task, even though the transfer task employed a motor sequence identical to that involved during training. This specificity derives, apparently, from the nature of what is learned. Despite the identity of motor responses, the transfer task required different production rules from those employed during training. (In the training task, response selection depended on stimulus color, whereas in the transfer task it depended on stimulus location.) It appears that knowledge embedded within one set of productions will not transfer to a task requiring different productions. The evidence suggests, however, that the development of explicit declarative knowledge may facilitate the transfer of skilled performance.

This work will be presented at the annual meeting of the Psychonomic Society in November. In addition, a manuscript summarizing these findings will be submitted to the Journal of Experimental Psychology: Learning, Memory, and Cognition.

Two other issues involving the relation between procedural and declarative knowledge are being investigated. One experiment is investigating whether patients with Huntington's disease, which involves lesions of the basal ganglia, demonstrate an impairment in procedural learning without a deficit in declarative learning. Such a pattern would contrast with the

results we obtained from amnesic patients with Korsakoff's syndrome or Alzheimer's disease, who showed the opposite pattern. This would constitute evidence of a double dissociation of procedural and declarative learning, which would support the hypothesis that these are independent systems. More specifically, this work is relevant to the hypothesis that the basal ganglia are importantly involved in some forms of procedural learning.

The second issue concerns whether this distinction between procedural and declarative knowledge extends to the verbal system. Or is it the case that the verbal system is so phylogenetically recent that verbal knowledge is necessarily declarative? The tasks used in most of this work assess the acquisition of a spatial sequence. But one series of experiments investigating the acquisition of a verbal sequence has been completed. In the initial experiments on this topic, a single word was presented on each trial and naming latencies were recorded. The set of four words appeared in either a 10-trial repeating sequence or a random sequence. Using this task, no evidence was found in the response latencies that subjects learned the sequence, unless they acquired explicit declarative knowledge of it. In other words, there was no clear evidence of procedural learning.

It was possible that this outcome occurred because naming is a relatively automatic response. Unlike other responses (e.g., lexical decision), naming is little affected by contextual

factors and is clearly a response that is highly learned before subjects enter our study. Thus, in subsequent experiments, a categorization task was used instead of a naming task. When each word appeared, subjects were to say aloud the category to which it belonged. In this task, evidence of procedural learning was found regardless of whether subjects acquired explicit declarative knowledge of the sequence. These findings suggest that procedural learning occurs in the verbal domain as well as the spatial domain. David Knopman, Marilyn Hartman, and Mary Jo Nissan are preparing a written report of this work for submission to the Journal of Experimental Psychology: Learning, Memory, and Cognition.

Elizabeth Stuck and Mary Jo Nissen have collaborated on the development of a connectionist model of performance on the tasks used in studying procedural learning in amnesic patients and normal subjects. The current version of the model has three levels of nodes with all possible forward connections between layers but no within-layer connections. This version runs in LISP on a SUN workstation. The goal is to get the model to learn the repeating sequence that is embedded in a series of trials by using back-propagation techniques, such that the number of cycles it takes the appropriate output node to reach threshold is progressively less with training on a repeating sequence than on a random sequence.

Peter Bullemer, an advanced graduate student in psychology, is conducting his dissertation on the nature of the expectancies

that subjects develop in the course of procedural learning. As subjects continue to respond to events occurring in a repeating sequence, their responses become progressively faster; they seem to develop expectancies regarding the next event. One might consider these to be consciously available expectancies that are driving performance. However, amnesic patients, who also show this progressive reduction in reaction time, are not aware of the existence of the repeating sequence and cannot predict accurately what the next event will be. Those findings suggest that the "expectancies" that are facilitating performance are not necessarily consciously available. In an effort to clarify the nature of these expectancies, Bullemer is conducting a series of cost-benefit experiments. Nonamnesic subjects receive varying amounts of training on the repeating sequence and then, in subsequent blocks of trials, they occasionally receive a "violation" trial in which the stimulus that is presented violates the preceding sequence that has been acquired. One of the major dependent variables of interest is whether response times on these violation trials is slower following training on the sequence than following training on a random sequence. The presence of such slowing (or "cost" as compared to a neutral condition) has been related to attentional processes by Posner and his colleagues. Bullemer is particularly interested in whether subjects who report that they did not notice a repeating sequence and who cannot generate the sequence demonstrate cost on violation trials.

## Image Enhancement in Human Vision

The purchase and set-up of hardware has demanded substantial time and effort in the Visual Psychophysics Laboratory. There was a long delay before the image-processing equipment was shipped. Initial malfunctions in the image-processing equipment lead to further delays associated with the return of the faulty equipment to the manufacturer and the correction of the problems.

The hardware configuration has nearly reached completion, consisting of the following hardware: A Conrac 7241 RGB high-performance color video monitor displaying true-color images from three Imaging Technology FG-512/AT video frame buffers controlled by an IBM AT linked to the Sun network. The Sun network is used for image storage and computationally-intensive image-processing, with the IBM AT used for real-time control in experimental presentations.

Networking software allows images to be transferred bidirectionally between Sun and AT. Software routines have been developed for the capture and display of images. Additional programs have been developed for Fourier transform and filtering of images, histogram equalization, and other image-enhancement algorithms. Also, programs have been written for testing and calibrating the video display.

A major goal has been to develop and test image-enhancement algorithms. A psychophysical procedure has been designed to

obtain quantitative evaluation of arbitrary enhancement algorithms. This procedure is used in an experiment testing face-recognition at very low contrasts, evaluating the effectiveness of different image-enhancement techniques. Several types of enhancement are of interest: (1) Local-adaptive filtering, with enhancement locked to local characteristics of the image. One such algorithm has been implemented to enhance local high-frequency image details as a function of the local mean luminance, avoiding problems of gray-scale saturation. (2) Gray-level histogram equalization has been proposed as a form of image enhancement. Following the medical-imaging work of S. Pizer, a form of local histogram equalization with interpolation has been implemented. The effect is to enhance images based on the statistics of local patches. The psychophysical procedure will be used to quantitatively evaluate the efficacy of this type of image enhancement. Data collection will begin once the hardware configuration and software development is complete.

Work on image-enhancement in different bands of color, and image-processing where color and spatial-frequency are conjoined will build upon the results from the experiments now in progress.

## Detection and Recognition of Complex Auditory Signals by Human Observers

The proposed research within the Auditory Psychophysics Laboratory consists of experimental and theoretical work aimed at

developing a descriptive model which can account for the detection and recognition of spectrally complex auditory signals. Since the recent initiation of this project, two major experimental studies have begun. One study examines the ability to extract information about temporal relationships between stimulation in different frequency-selective auditory "channels". More specifically, it was shown that relatively small phase differences between the envelopes of sinusoidally amplitude-modulated tones can be detected over a wide range of modulation frequencies and over a wide range of relative carrier frequencies. The direct conclusion of this initial research is that the auditory system can perform a true "cross-channel" comparison and that the "within-channel" interactions which are present in most complex signals can not explain certain types of complex perceptions. The implication is that this higher order ability must be considered to understand perception of complex auditory signals. This research will be presented at the November, 1987 meeting of the Acoustical Society of America.

The second project pursued a phenomenon which questions our understanding of basic auditory processing. Specifically, it was shown that sweep-frequency maskers can produce substantially more masking of a brief tonal probe than does an "unswept" masker at the probe frequency. The swept masker has far less energy in the "critical band" centered at the probe frequency and therefore should produce <u>less</u> masking. Experiments have been completed that rule out several possible explanations for this phenomenon

and indicate very peculiar masker-level dependencies. These dependencies suggest that something other than traditional "energetic" masking is occurring and, possibly, that the phenomenon reflects a complex process of envelope waveshape discrimination. The research will be presented at the November, 1987 meeting of the Acoustical Society of America.

The theoretical work has been preparatory and has primarily involved implementing the Sun/UNIX system acquired through the support of this grant. Two major accomplishments have been achieved. A signal processing package, ISPUD, has been implemented on the Sun. This is a powerful, LISP-like environment developed at MIT and run under their VAX/VMS system. Extensive modifications were necessary to run this package under UNIX. We have begun using ISPUD/UNIX for simulations of simple auditory phenomenon and for generation of complex waveforms to be used in our psychophysical research.

The second project involved implementing a realistic cochlear model (Allen, 1985) on the Sun. This provides part of the front end for a more detailed model and is fundamental to the theoretical work proposed under this project. The model is at the stage where it has helped us to understand the possible basis for the sweep-frequency masking paradox described above.

A Process Model for the Comprehension and Recall of Texts

The research conducted in the Psycholinguistics Laboratory

has been directed toward developing and testing a computer model of text comprehension and recall. Substantial progress has been made toward achieving these goals. An initial version of the model has been implemented in Sun Common Lisp. This model includes a comprehension component and a recall component. The comprehension component of the model takes as input a list of semantic propositions representing the content of a text, and a list of causal relationships among those propositions. It adds propositions to a limited-capacity short-term memory one at a time, just as human readers do. As each proposition is added to short-term memory a link is created between it and any other propositions in short-term memory. A strength is assigned to each link, depending on the nature of the semantic relationship between the linked propositions. Causally related propositions are assigned a stronger link than referentially related propositions, which are assigned a stronger link than propositions with no semantic relationship. Each time a sentence boundary is encountered, short-term memory is purged of all but a small number of propositions in order to make room for the next sentence. Only the propositions with causal antecedents but no consequences in the earlier text are retained in short-term memory. This assumes that readers engage in a simple form of causal reasoning during comprehension, always focusing their attention on the end of the causal chain that can be traced backward to the opening of a text. After short-term memory has been purged, the strength of association between all propositions

not deleted is incremented. This process results in a representation of a text in long-term memory that consists of a connected network of propositions with strengths assigned to each link. The strength of association between any two propositions is determined by the nature of the semantic relationship between them and the amount of time they spend in short-term memory together.

The retrieval component of the model takes as input the propositional network produced by the comprehension component. It's output is a list of "recalled" propositions. This part of the model includes a strategic process that selects retrieval cues and a stochastic retrieval process that uses those cues to probe long-term memory and return a recalled proposition. The strategic process always selects as cues propositions whose antecedents, but not consequences, have been recalled. This amounts to assuming that recalling a text also involves causal reasoning, that someone trying to recall a text will attempt to find a sequence of causal states that form a chain beginning with the opening of the text and proceeding to its final outcome. The retrieval process used by this model is based on Gillund and Shiffrin (1984, Psychological Review), a model that has been well tested in the list-learning domain.

As an initial test of this model it was run 100 times on a simple narrative text (ten sentences long). When the resulting free recall probabilities for each proposition in this text were compared to those observed in human subjects, a correlation of r

= .63 was observed. This indicates substantial similarity between the performance of our model and that of human readers. This success can be attributed to three key elements of the model: (1) The process that determines the contents of short-term memory during comprehension. (2) The assumption that the strength of association between two propositions is determined by the nature of the semantic relationship between them. (3) The process that selects retrieval cues during recall. When any of these elements is removed from the model, a significant decrement in its performance is observed.

The model described here has several psychologically meaningful assumptions built into it. First is the assumption that subjects always retain in short-term memory the last proposition, or group of propositions, with antecedents but no consequences in the preceding text. A number of experiments have been completed to verify this assumption. In one experiment the length of time a proposition remains in short-term memory and the number of other propositions it becomes connected to as a result was predicted by the model. These two variables were found to account for more than 30% of the variance in the free recall performance of human subjects. Several competing models of short-term memory allocation during comprehension were examined but none performed as well. In a second experiment, reading time (per clause) was found to vary as a function of the causal structure of a text. Specifically, each causal connection a clause has to other clauses increases its reading time, but only

if propositions from the other clause remain in short-term memory (according to the model). In a third experiment subjects were presented with probe words as they read and asked to verify that those words had occurred earlier in the text. If the word was from a proposition that the model predicts is in the subject's short-term memory, response times were over 100 msec faster than if they were not. Taken together, these three experiments provide strong support for the model's assumptions about the allocation of short-term memory during comprehension.

The assumption that the strength of association between two propositions from a text depends on the nature of the semantic relationship between them has also been tested experimentally. Both priming and cued-recall procedures have been used to verify that causally related propositions are more strongly related in long-term memory than referentially related propositions, which (in turn) are more strongly related than propositions that co-occur in short-term memory but have no semantic relationship to one another. This confirms a second basic assumption of the model. A third assumption that needs to be verified, but has not yet been examined, is that causal reasoning determines the selection of retrieval cues during the recall of a text. A verbal protocol experiment is now being designed to verify this assumption.

## Articles
(Listed Chronologically)

Published:


Nissen, M. J. (1986). Strategies, rules, and domain specificity. In M. Perlmutter (Ed.), Perspective on intellectual development. The Minnesota Symposium on Child Psychology. Volume 19 (pp. 49-56). Hillsdale, NJ: Erlbaum.

Nissen, M. J. (1986). Neuropsychology of attention and memory. Journal of Head Trauma Rehabilitation, 1, 13-21.

Corkin, S., Growdon, J. H., Sullivan, E. V., Nissen, M.J., & Huff, F. J. (1986). Assessing treatment effects: A neuropsychological battery. In L. W. Poon (Ed.), Handbook for clinical memory assessment of older adults (pp. 156-167). Washington, D.C.: American Psychological Association.

Nissen, M. J., & Bullemer, P. (1987). Attentional requirements of learning: Evidence from performance measures. Cognitive Psychology, 19, 1-32.

Nissen, M. J., Knopman, D. S., & Schacter, D. L. (1987). Neurochemical dissociation of memory systems. Neurology, 37, 789-794.

Knopman, D. S., & Nissen, M. J. (1987). Implicit learning in patients with probable Alzheimer's disease. Neurology, 37, 784-788.

Fletcher, C.R., & Bloom, C.P. (1987). Causal reasoning in the construction of a propositional textbase. Proceedings of Ninth Conference of the Cognitive Science Society. Englewood Cliffs, NJ: L. Erlbaum Assoc.


In Press:


Nissen, M. J., Ross, J. L., Willingham, D. B., Mackenzie, T. B., & Schacter, D. L. (in press). Memory and awareness in a patient with probable Alzheimer's disease. Brain and Cognition.

Nissen, M. J. (in press). Bridging some gaps in cognitive neuroscience. Contemporary Psychology.

Viemeister, N.F. (in press). Evidence for cross-channel processing in detection of envelope phase disparity. J. Acoust. Soc. Am.

Viemeister, N.F. (in press). Masking of short tone bursts by frequency sweeps. J. Acoust. Soc. Am.

In Preparation/Submitted:

Bloom, C.P., Fletcher, C.R., Reitz, L., & Shapiro, B. (In preparation for submission to Memory and Cognition). Causal reasoning in comprehension: Evidence from reading times.

Fletcher, C.R. (In preparation for submission to Cognitive Science). A model of narrative comprehension and recall.

Fletcher, C.R., & Bloom, C.P. (Under review for publication). Causal reasoning in the comprehension of simple narrative texts. Journal of Memory and Language.

Fletcher, C.R., & Hummel, J. (In preparation for submission to Journal of Experimental Psychology: Learning, Memory, and Cognition). On-line measures of causal reasoning in narrative comprehension.

Freed, D. M., Corkin, S., Growdon, J. H., & Nissen, M. J. (Under review for publication). Behavioral and neurochemical evidence or noradrenergic pathology in a subgroup of patients with Alzheimer's disease. Neuropsychologia.

Nissen, M. J., Willingham, D. B., & Hartman, M. (Under revision for publication). Explicit and implicit remembering: When is learning preserved in amnesia? Neuropsychologia.

Nissen, M. J., Willingham, D. B., & Bullemer, P. (In preparation for submission to the Journal of Experimental Psychology: Learning, Memory, and Cognition). On the nature and specificity of procedural learning.

Nissen, M. J., Case, L., & Isenberg, L. (In preparation for submission to the Journal of Experimental Psychology: Human Perception and Performance). Attentional processing and the independence of color and shape.

## Participating Personnel

Faculty:

Charles R. Fletcher, Ph.D. Assistant Professor of Psychology, University of Minnesota. (Principle Investigator)

Gordon E. Legge, Ph.D. Professor of Psychology, University of Minnesota. (Co-Investigator)

Mary Jo Nissen, Ph.D. Associate Professor of Psychology, University of Minnesota. (Co-Investigator)

Neal F. Viemeister, Professor of Psychology, University of Minnesota (Co-Investigator)

Others:

Charles P. Bloom, Ph.D. Post-doctoral research associate.

Peter Bullemer. Graduate student (Will receive Ph.D. in Psychology in December 1987).

Meg Cheesman. Graduate student.

David Fabray. Graduate student.

Deborah Fantini. Graduate student.

Catherine Harman. Programmer/technician.

Marilyn Hartman. Graduate student (Was awarded Ph.D. in Psychology in June 1987. Dissertation title: "A cognitive-neuropsychological study of semantic representation in dementia of the Alzheimer type.")

John Hummel. Graduate student.

Cynthia Johnson. Undergraduate student.

Marilyn Kronenberg. Undergraduate student.

Andrew Luebker. Graduate student.

Chad Marsolek. Undergraduate student.

Thomas Mittelstaedt. Graduate student.

Alberto Recio. Graduate student (Will receive M.S.E.E. in December, 1987).

Laura Reitz. Graduate student.

Charles Schaeffer. Graduate student.

Mary Smith. Undergraduate student.

Benjamin Stiegler. Programmer.

Elizabeth Strickland. Graduate student.

Elizabeth Stuck. Graduate student.

Daniel Willingham. Graduate student.

Bertrand Wilson. Undergraduate student.

## Conference and Colloquium Presentations

Nissen, M.J. "Characteristics of the Procedural Memory System." Presentation at the Office of Naval Research contractors' meeting, Eugene, Oregon. October 9, 1986.

Nissen, M.J., Corkin, S., Growdon, J.H., Huff, F.J., Keane, M.M., Lieberman, H., Gruber, A., & Russo, J. "Dissociation of Visual Capacities in Alzheimer's Disease." Poster presented at the annual meeting of the Society for Neuroscience, November, 1986.

Nissen, M.J., Case, L., & Isenberg, L. "Attentional Processing and the Independence of Color and Shape." Paper presented at the annual meeting of the Psychonomic Society, New Orleans. November 15, 1986.

Nissen, M.J. "Dissociation of Memory Systems: Preserved Learning in Amnesia." Invited colloquium, Institute of Child Development Colloquium Series, University of Minnesota. December 4, 1986.

Nissen, M.J. "Studies of Implicit Learning." Invited presentation, Neuro-psychology Research Group, MIT, Cambridge, MA. February 6, 1987.

Nissen, M.J. "Implicit Memory in Organic and Functional Amnesia." Grand Rounds, Department of Psychiatry, University of Minnesota. February 10, 1987.

Nissen, M.J., Case, L., & Isenberg, L. "Perceptual Independence of Color and Shape." Poster presented at the annual meeting of the Association for Research in Vision and Ophthalmology, Sarasota, FL. May 8, 1987.

Nissen, M.J. "Relations Between Memory and Awareness." Invited colloquium, Minnesota Center for Philosophy of Science, Workshop on New Directions in the Philosophy of Cognitive Science. University of Minnesota. May 13, 1987.

Nissen, M.J. "Understanding Memory by Studying Amnesia." Invited address, Midwest Neuropsychology Group, Minneapolis, MN. May 14, 1987.

Fletcher, C.R., & Bloom, C.P. Causal reasoning in the construction of a propositional textbase. Paper presented at the annual meeting of the Cognitive Science Society, Seattle, WA. July 18, 1987.

Nissen, M.J. "Evaluating Amnesia in Multiple Personality Disorder." Invited address at conference on Psychological Concepts and Dissociative Disorders, Dalhousie University, Halifax, NS. August 26, 1987.

Bloom, C.P., Fletcher, C.R., Reitz, L., & Shapiro, B. An online assessment of causal reasoning in the comprehension of narrative texts. Paper to be presented at the annual meeting of the Psychonomic Society, Seattle, WA. November 8, 1987.

Nissen, M.J., Willingham, D., & Bullemer, P. "On the Nature and Specificity of Procedural Learning." Paper to be presented at the annual meeting of the Psychonomic Society, Seattle, WA. November 8, 1987.

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